NASA TECHNICAL NOTE

NASA TN D-3494

NASA TN D-3494

AN ERROR DETECTION AND CORRECTION APPROACH TO THE TIME DECODING PROBLEM

by A. M. Demmerle, T. J. Karras, and P. J. McCeney

Goddard Space Flight Center
Greenbelt, Md.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION • WASHINGTON, D. C. • AUGUST 1966

AN ERROR DETECTION AND CORRECTION APPROACH

TO THE TIME DECODING PROBLEM

By A. M. Demmerle, T. J. Karras,
and P. J. McCeney

Goddard Space Flight Center
Greenbelt, Md.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

For sale by the Clearinghouse for Federal Scientific and Technical Information
Springfield, Virginia 22151 – Price $1.00

ABSTRACT

The error detection and correction capabilities available in redundant information have been used in a system which copes with a large variety of erroneous time code readings from analog magnetic tapes. The system both decodes and evaluates the redundant information contained in the incoming serial decimal time code and binary coded decimal time code and compares this decoded and evaluated time reading with previously received and evaluated time information. The output time word resulting from these comparisons and evaluations also contains flags which can be analyzed to indicate the degree of confidence which the user can place in its accuracy. The decoder also contains self-checking circuits to reduce the probability that a malfunctioning decoder component will cause an undetected incorrect time reading.

CONTENTS

AN ERROR DETECTION AND CORRECTION APPROACH TO THE TIME DECODING PROBLEM

by
A. M. Demmerle, T. J. Karras,
and P. J. McCeney
Goddard Space Flight Center

INTRODUCTION

The data reduction facilities at the Goddard Space Flight Center process magnetic tapes containing data received from the scientific satellites. The time code which indicates the data reception time in Universal Time is produced by a time encoder located in the tracking station. It is serially recorded on a channel of the tape adjacent to those on which the incoming data are being recorded (see Appendix A). Tracking networks and supporting computer facilities correlate the satellite's location in space with time and receiving networks and data reduction facilities correlate the satellite's data with time. Since a majority of the data from the satellites use time as an independent variable in correlating data with position, erroneous time readings are a source of genuine concern to the experimenters. In order to reduce the time reading errors to a minimum, an error detecting and correcting time decoder has been designed for use with the data reduction facilities at GSFC. This system was first used for processing data from E-OGO, the first of the Orbiting Geophysical Observatories.

TIME CODES

The two time codes adopted for use by the Goddard Space Flight Center are the serial decimal (SD) time code and the binary coded decimal (BCD) time code.

The Serial Decimal Time Code

The SD time code (Figure 1a) consists of time data in digits from tens of seconds through tens of hours. It has a resolution of one second, although it is accurate to 1 millisecond. The resolution can be improved to one millisecond with the use of a linearizing (reference) frequency, which is either 100 kilocycles or 10 kilocycles and is derived from the same tracking station precision oscillator from which the time code is derived (see Appendix A). Frequency modulation is used for recording the SD signal on tape.

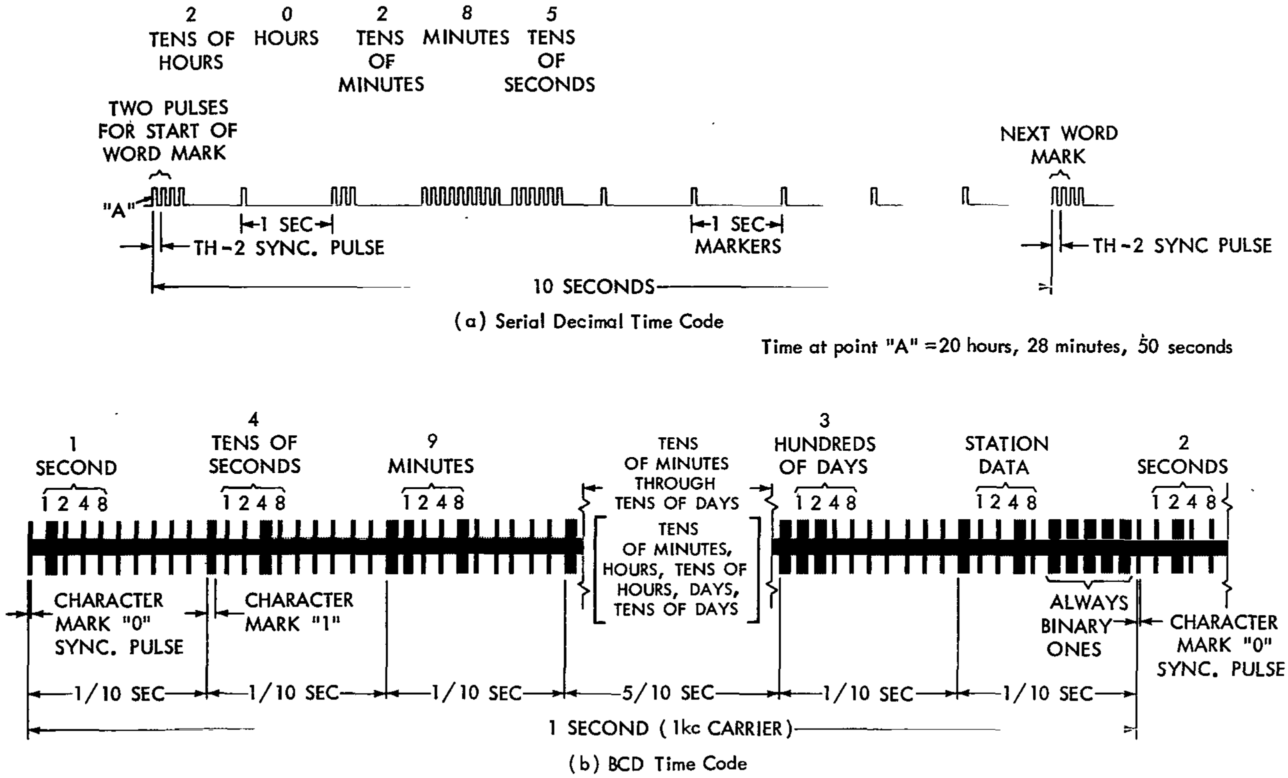


Figure 1—NASA time codes: (a) Serial decimal time code, (b) BCD time code.

The Binary Coded Decimal Time Code

The BCD time code (Figure 1b) presents time data in digits from seconds through hundreds of days. This includes four bits per second of "station data" to identify a magnetic tape recording by including, for example, station identification, satellite identification, the year of recording, etc. The resolution of the BCD time code is one millisecond because the 1 kc carrier frequency is a part of the code. A binary zero is represented by an approximate three-to-one increase in the voltage amplitude of the carrier for two complete cycles. A binary one is represented by a similar carrier voltage increase for six complete cycles. The spectrum of the BCD time code includes no significant energy more than ±400 cycles away from the 1 kc center frequency; therefore, this code can be mixed with other signals on a single channel of a tape recording to conserve channels. At present, the servo signal, which is 60 cycles per second modulation of 18.24 kc, is mixed with the BCD time code.

PREVIOUS METHODS OF TIME-DECODING

In the data reduction process at GSFC, the two methods previously used for correlating time with data were the multiple-read-in method and the single-read-in method. In the multiple-read-in method, the decoder collects the time data from the magnetic tape and formats the data as a single time reading, once every ten seconds for SD or once per second for BCD. This reading is updated by 1 kc pulses until another full time reading is collected. The main disadvantage with this method is that any temporary perturbation in the time signal appears as an error in the time reading. In the single read-in method the operator observes the register display; and when it appears to be monotonically increasing, he transfers the decoded time word from the decoder into a register where it is updated with 1 kc pulses. The main disadvantages of this method are that only one time reading is actually correlated with the data, and that potentially valuable data are lost each time the register is reset, since the operator must wait several seconds to be sure that the decoder output is increasing monotonically before setting the updated register.

TIME-DATA CORRELATION

Figure 2 shows various possible errors in, and conditions of, a decoder's output. Errors passed on by the decoder can increase the cost of the data reduction process. In later processing of the data, general purpose computers are used to perform such operations as scaling, converting, sorting, and special arithmetic or formatting operations as may be necessary for a specific data use. If undetected errors in the time data are recorded on the digital magnetic tape, computer time must be spent in searching for these errors. For pulse frequency modulation (PFM) telemetry, for example, the digital tape is formatted to have a time reading once per frame, which occurs at approximately constant time intervals. The computer measures the difference between two consecutive time readings, and if this difference falls outside certain tolerance limits, an error is indicated. If this occurs frequently enough, complete reprocessing is required.

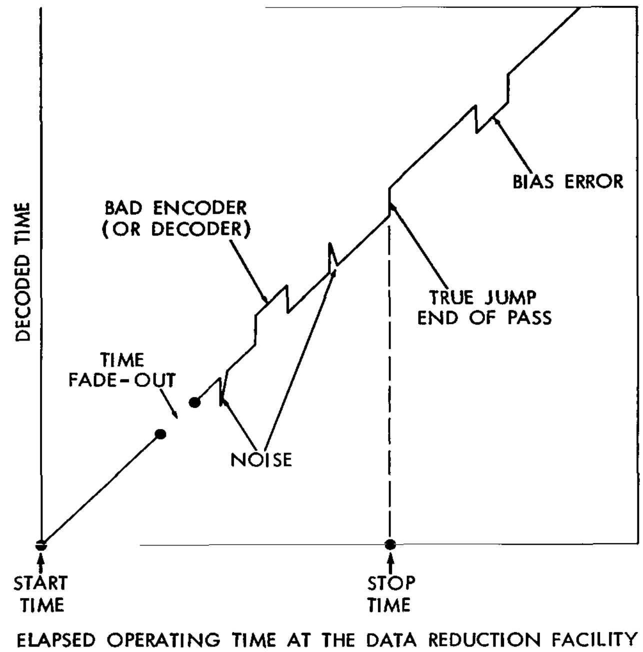


Figure 2—Possible conditions of a time decoder output.

THE SYSTEMS APPROACH TO TIME ERROR DETECTION

The engineering problem is in choosing and designing a system which, while minimizing operator intervention, optimizes the trade-off of cost-complexity vs. index of confidence in its output readings. The ideal system would be one that could provide correct time readings regardless of errors in the input signal. A more realistic system is one for which the output can be assigned an index of confidence which is a function of the condition of the input signal and the cost and complexity of the system. The final choice of an optimum system depends upon the statistics of the probability of occurrence of any given type of error.

CATEGORIZING ERRORS

The systematic design of a system which deals with errors requires categorizing them. There are several ways to classify these errors, e.g., those caused by the encoder, decoder, or the transmission link; those caused by equipment or the operators.

The most useful categorization seems to be the consideration of the various conditions of the signal at the input to the decoding system. Malfunction of the decoding equipment can be shown to be equivalent to some of these input signal conditions in the list that follows.

1. The BCD code exists.
   - a. It is correct.
   - b. It is incorrect sporadically.
   - c. It is incorrect regularly (bias).
2. The BCD code does not exist.
   - d. temporarily.
   - e. permanently.
3. The SD code exists.
   - f. It is correct.
   - g. It is incorrect sporadically.
   - h. It is incorrect regularly (bias).
4. The SD code does not exist.
   - i. temporarily.
   - j. permanently.
5. The linearizing frequency exists.
   - k. It is correct.
   - l. It is incorrect sporadically.
   - m. It is incorrect regularly (bias).
6. The linearizing frequency does not exist.
   - n. temporarily.
   - o. permanently.

The conditions listed can exist in only the eight possible combinations of categories as follows:

2, 4 and 5	2, 4 and 6
2, 3 and 5	2, 3 and 6
1, 4 and 5	1, 4 and 6
1, 3 and 5	1, 3 and 6

The other combinations are impossible because categories 1 and 2, 3 and 4, and 5 and 6 are mutually exclusive.

AN IDENTIFICATION AND CORRECTION SYSTEM

This system detects and identifies errors (see Appendix B) and corrects certain types. In addition, it provides time readings as pure binary numbers which express either the number of elapsed milliseconds of the year, or the number of elapsed milliseconds of the day and the day of the year, as well as the mixed modulus system where time is put on the digital magnetic tape as a BCD number indicating the day of the year, hour of the day, minute of hour, etc. Providing both formats helps eliminate costly conversion time later in the data analysis process.

The time decoding system has been designed to consider (1) a low signal-to-noise ratio at its input, where noise includes white noise, impulsive noise, and stray modulation; (2) genuine errors in the input signal which may be caused at the encoder; (3) signal fade-out; and (4) decoder malfunction (see Figure 2).

There are only four combinations of bad input signal from the previously listed input signal conditions which will render incorrect output readings without the system recognizing it:

1. (c, h) a BCD bias error and an SD bias error where the two bias errors are equal.

2. (c, j) a BCD bias error and no SD code anywhere on the tape.

3. (e, h, k) no BCD code anywhere on the tape, and an SD bias error.

4. (e, h, n) no BCD code anywhere on the tape, an SD bias error, and the linearizing frequency missing for very short periods of time.

The seriousness of these limitations, of course, depends upon the nature of the input signal, the frequency of occurrence of the unmanageable input signal combinations, and the consequences of allowing uncorrected errors. After a careful consideration of these factors, it was presumed it would not be economically justified to design features into the system to compensate for the four types of irregularities listed above. These can be corrected later in the data reduction process by correlation with a clock within the satellite whose value is telemetered along with the other satellite data or by other methods. Early satellites did not contain a clock per se, but the obvious value of a local satellite clock has led to its inclusion in the later and larger satellites. Figure 3 is a block diagram of the proposed system. A brief description of the elements of the system follows.

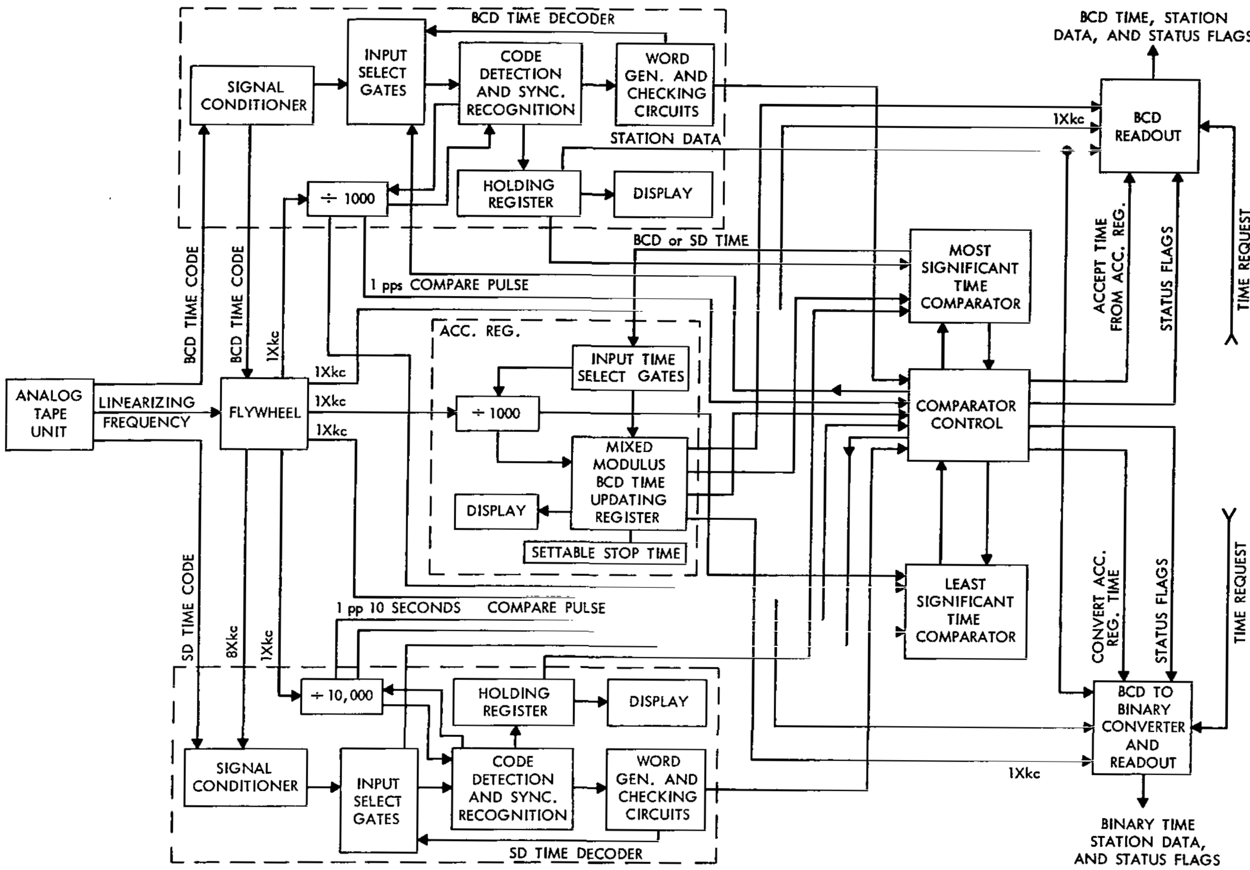


Figure 3—Time decoder subsystem block diagram.

1. Flywheel

The purpose of the flywheel is to produce a nominal 1 kc signal which is phase-locked to its input, if there is an input, and to maintain an output at the frequency of the last input if the input disappears. The flywheel has a selectable bandwidth of ±5% or ±10%. This means that the standard frequency at the input can vary as much as the selected bandwidth and yet the output of the flywheel will continue to maintain phase-and-frequency-lock with its input, thereby compensating for input tape stretch, input tape recorder speed variation, etc. The flywheel also supplies the 8 kc signal to the SD decoder front-end circuitry.

Two different "real time" linearizing frequency signals, 100 kc or 10 kc may be available to the time decoder. They are shaped with a Schmitt trigger circuit. If the input is the 100 kc signal, it is divided down to 10 kc in the "frequency selector." If the input is the 10 kc signal, it is passed straight through this selector. The 10 kc out of the frequency selector is again divided by ten in the "frequency divider" in order to produce 1 kc. The frequency divider is reset by the

1 kc carrier from the BCD code detector to assure that synchronization exists between both 1 kc signals entering the flywheel synchronizing selector. This selector supplies 1 kc to the flywheel from the BCD time code if that signal is present. If, however, the linearizing frequency fades out, the 1 kc from the linearizing frequency will automatically be used to drive the flywheel.

2. BCD Decoder

a. Signal Conditioner

These filters were designed to extract the BCD time code from the incoming signal which can also contain an 18.24 kc carrier frequency that is amplitude-modulated with 60 cycles for tape speed control. The filters have been designed to attenuate both the carrier and the servo signal at time compressions of 1, 2, 4, 8 and 16 (i.e., tape speed-ups). The bandwidth of the 1 kc filter is 800 cycles. These filters are conventional T-type capacitor and indictor low pass-high pass filters.

b. Code Detection, Sync Recognition, and Word Generator

The purpose of this code detector is to accept and adequately deal with amplitude variations of the input signal. It will handle variations of from 0.5 to 8.0 volts peak-to-peak. It also demodulates the time code from the carrier. The decoder discriminates between the "ones" and "zeros" of the BCD time code and presents this decoded time to the readout circuitry. The BCD decoder contains a "one" detector circuit, shift pulse generator, pattern recognizer, synchronous shift register, logic counter and a binary word generator is used for checking the BCD decoder circuits.

c. Holding Register and Display

This unit receives the decoded BCD time word in parallel form from the shift register in the BCD decoder unit and holds each decoded word for display and for making comparisons.

3. SD Decoder

a. Signal Conditioner

The SD code signal at 1X tape speed consists of pulses which are 40 to 50 milliseconds wide and occur at a maximum rate of ten pulses per second. This signal is particularly susceptible to degradation by impulsive and white noise which makes the reading of this code susceptible to error. Digital techniques are employed to extract this signal from the noise. The DC voltage of the base line of these input pulses varies between plus one-half volt and minus one-half volt. A DC restoring circuit is used to assure a constant bias level to the input of the decoder.

b. Code Detection, Sync Recognition, and Word Generator

The decoder is used to synchronize the SD time code and present the decoder time to the readout register. It also checks the SD system by way of a word generator.

c. Holding Register and Display

This unit receives the SD decoded time word in parallel from the SD decoder and holds this information for ten seconds for display and for making comparisons with the decoded BCD word or the accumulating register.

4. Accumulating Register

The use of an accumulating register prevents possible sporadic errors in either of the decoded time words from being passed to the rest of the data processing facility. The time, as decoded in either the SD or BCD decoders, is automatically set into the accumulating register at the beginning of each data processing run and/or when the mode of operation switches between loops 1 and 2. The register is then updated by the 1 kc output of the flywheel. This accumulated time is available as an output and is also sent to the BCD-to-binary converter and BCD readout which presents time (milliseconds of the day and day of the year or milliseconds of the year) to the data processing facility. The accumulating register is displayed along with the BCD and SD decoded time words.

5. "Comparator" and "Comparator Control"

The "comparator" compares the decoded time with the accumulated time in the accumulating register. It also serves to make comparisons between the SD and BCD decoded time words. The "set in new word" unit operates in conjunction with the comparator to set a new word in accumulating register when the accumulating register is deemed incorrect. The comparator detects errors in the input signal and errors in the equipment itself, and is, therefore, one of the most basic elements of the system.

6. BCD-to-Binary Converter

This unit converts the time word in the accumulating register (seconds through hundreds of days) to a binary number representing either milliseconds of the year or milliseconds of the day and day of the year. The millisecond precision is obtained by updating the binary number derived from the time code with 1 kc. This converted and updated time word is presented to the data reduction facility upon electronic request. The format of this output is programmable.

The converter performs the conversion to binary by considering each BCD bit separately and weighting the bit according to the number of milliseconds it represents in the octal numbering system. For example, one second represents 1750 milliseconds in the octal system, and this is the weight assigned to this bit. As each of the 30 BCD bits is considered, its weighted value is added to the weighted values of the previously considered bits. The binary representation of the octal number that occurs after all 30 bits have been considered and weighted is the desired result. By adjusting the weight given to the bits representing the number of days, either milliseconds of the day and day of the year or milliseconds of the year can be made available as the conversion result.

The converter is designed to make an automatic internal test for component malfunction prior to every conversion. This test is made by sending a particular fixed word through the converter and checking the converter output to see that it is as expected. If the automatic test procedure indicates a component malfunction, an error light will warn the operator and the output will be flagged. The light will remain lit until the malfunction is repaired and then it will be extinguished automatically.

7. BCD Readout

This subsystem accepts a decoder time word, in parallel, from accumulating register. Its purpose is to provide a programmable time to the output. The status flags and station data are also presented to patch boards as a programmable output.

GENERAL OPERATION

This decoder makes use, when possible, of the built-in redundancy of having both the BCD and SD time signals available for processing. If only one of these two signals is present, it automatically considers only that one. The decoder automatically checks its internal circuitry; identifies (flags) the class of error which it has detected so that the experimenter can determine the amount of confidence to be placed in a decoded time work; can automatically delete the output and alert the operator when the time-density of errors exceeds some preset value; alerts the operator and deletes the output at previously known preset times. The features of alerting the operator at some preset time permits the immediate automatic detection of known times, such as the end of the recording of a particular satellite pass. This feature is especially useful when more than one pass is recorded on one analog magnetic tape.

The system requires no starting procedure or starting point on the data tape. Unlike previous time decoders, this system has neither manual single-read-in nor multiple-read-in modes of operation. It performs these operations automatically whether BCD or SD or both time codes are available.

A functional logic diagram of the time decoder showing the differing modes of operation of loop 1 and loop 2 is given in Figure 4. Figures 5a and 5b depict the actual flow of data in the comparator flow circuit. If the system has been reset, either by the system normalizer when the power is first turned on, or by pushing the master reset button, operation will begin in loop 1. In this loop, the decoded BCD time word will be compared with the accumulating register. If they compare, flag 1 will be presented to the buffer together with the time word. If they do not compare, flag 2 will be presented to the buffer accompanied by the time word.

In loop 1 the decoder will also determine if the serial decimal circuit is synchronized with the incoming serial decimal code. If the serial decimal circuit is in synchronism with the incoming signal, the appropriate part of the incoming BCD time word is compared with the SD time word. If they compare favorably, the accumulating register is updated and operation continues in loop 1. If they do not (flag 9), the BCD circuit is automatically checked for circuit malfunction. If there is no circuit malfunction, a determination is made as to whether or not the BCD circuit is synchronized with the incoming BCD time code. If it is synchronized a new BCD time word is set in the accumulating register and updated. If there is a BCD circuit malfunction, the BCD circuit operation is inhibited and the decoding function is shifted to loop 2, provided the SD circuit is synchronized with the incoming SD time code. Another way for the decoding function to shift to loop 2 is to have the incoming BCD time word and the accumulating register not agree for a number of consecutive times, where the number is selectable. Initially, the number is set for three times.

Operation of the decoding function in loop 2 is similar to that in loop 1 except that the serial decimal code is used in place of the binary coded decimal code. However, since the BCD loop is the more desirable loop, because of the BCD time code characteristics described under "Time Codes," the decoder will continually determine if operation in loop 1 is possible; and if so, it will shift the decoding function back to that loop.

ANOTHER DATA TIME CORRELATION PROBLEM

Another data-time correlation problem is that of determining the time of occurrence of events detected by the satellite when it is not in telemetry communication with the earth. These data are recorded in storage devices (e.g., magnetic core memories or magnetic tape recorders) in the satellite for telemetry transmission to the earth when commanded to do so by a tracking station. Because the data were collected some time before it was actually telemetered back to earth, the time it is received at the tracking station is only indirectly related to the time of occurrence of the event indicated by the data. Therefore, to correlate these data with time requires more than just a knowledge of the time the data are received at the tracking station. It also requires that some record of time must be contained within the satellite, and the data correlated with the time indicated by this time record both before and during storage.

One of the early techniques used in a satellite having PFM telemetry employed a tape recorder for data storage during the periods as the satellite circled the earth when it was not in communication with the earth. Upon command from a tracking station, the tape recorder played back its contents at a speed approximately fifty times that at which it was recorded. The tape was a continuous loop which ran in only one direction. When the satellite was commanded to play back the recorded data, the time of the command was marked on the receiving station tape recorder,

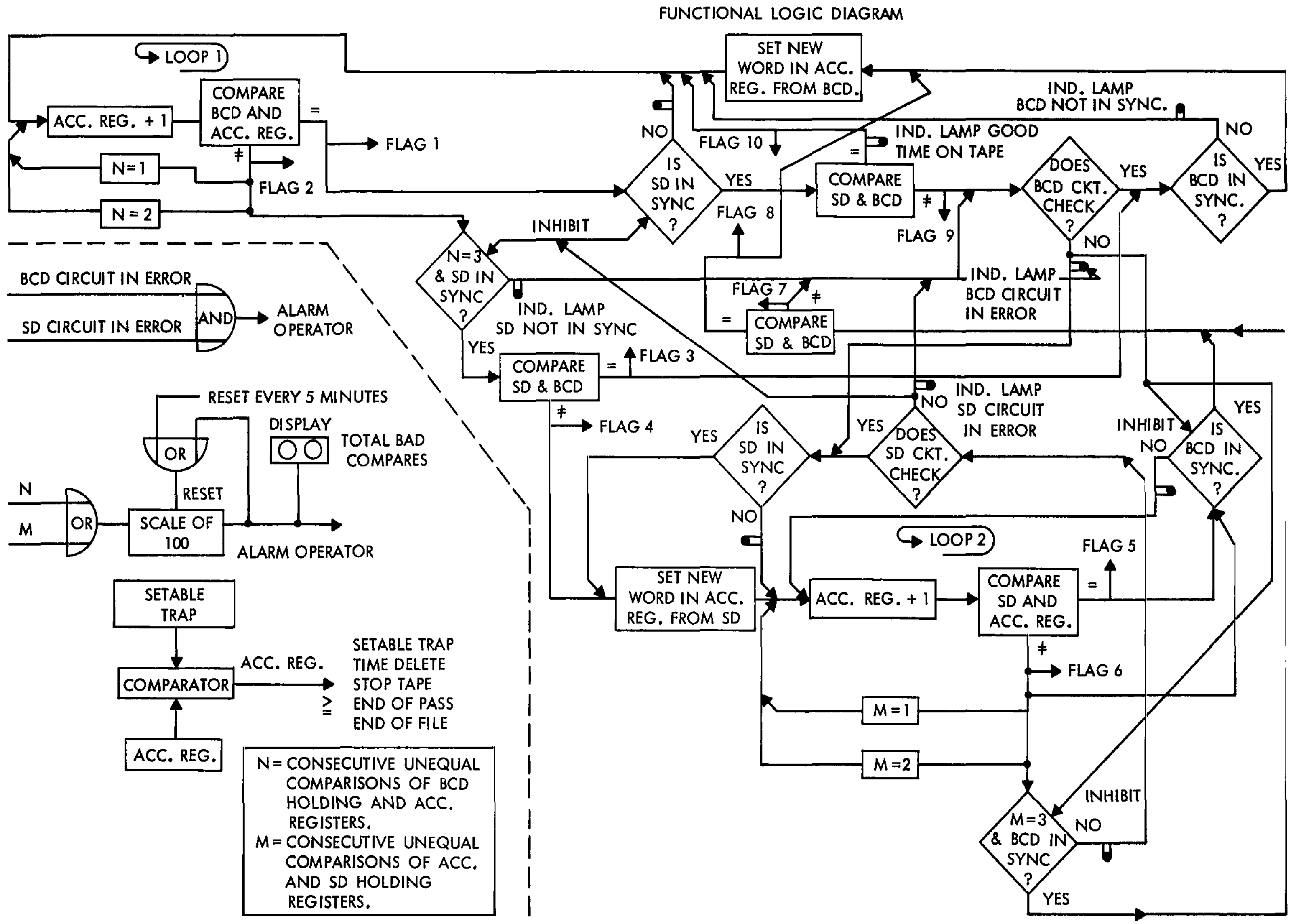
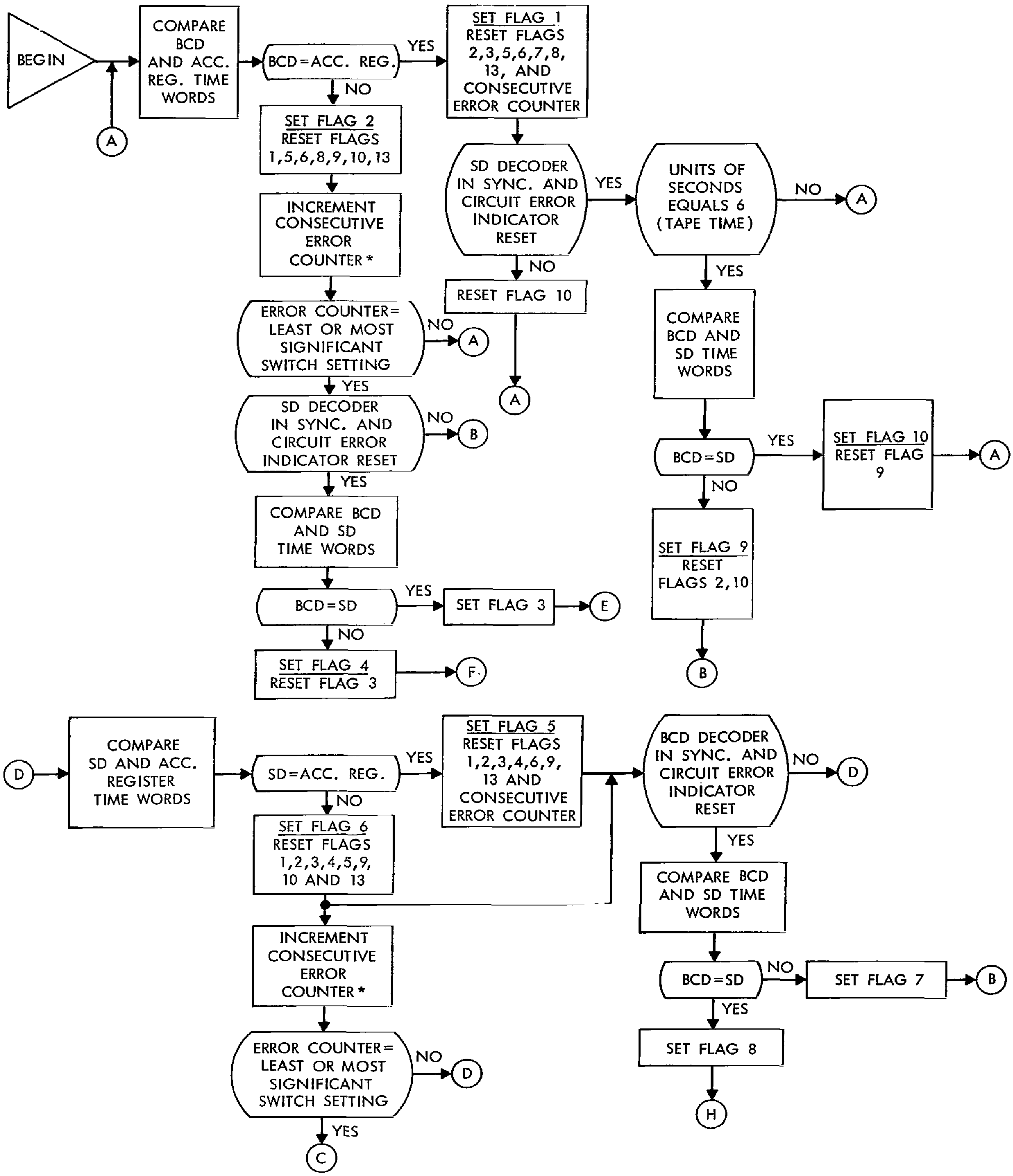


Figure 4—Functional logic diagram.



*THE SWITCH SETTINGS FOR THE LEAST SIGNIFICANT AND MOST SIGNIFICANT CONSECUTIVE ERROR COUNTERS FOR NOISELESS TIME CODES SHOULD BE 3 TO 5.

Figure 5—Comparator control flow diagram.

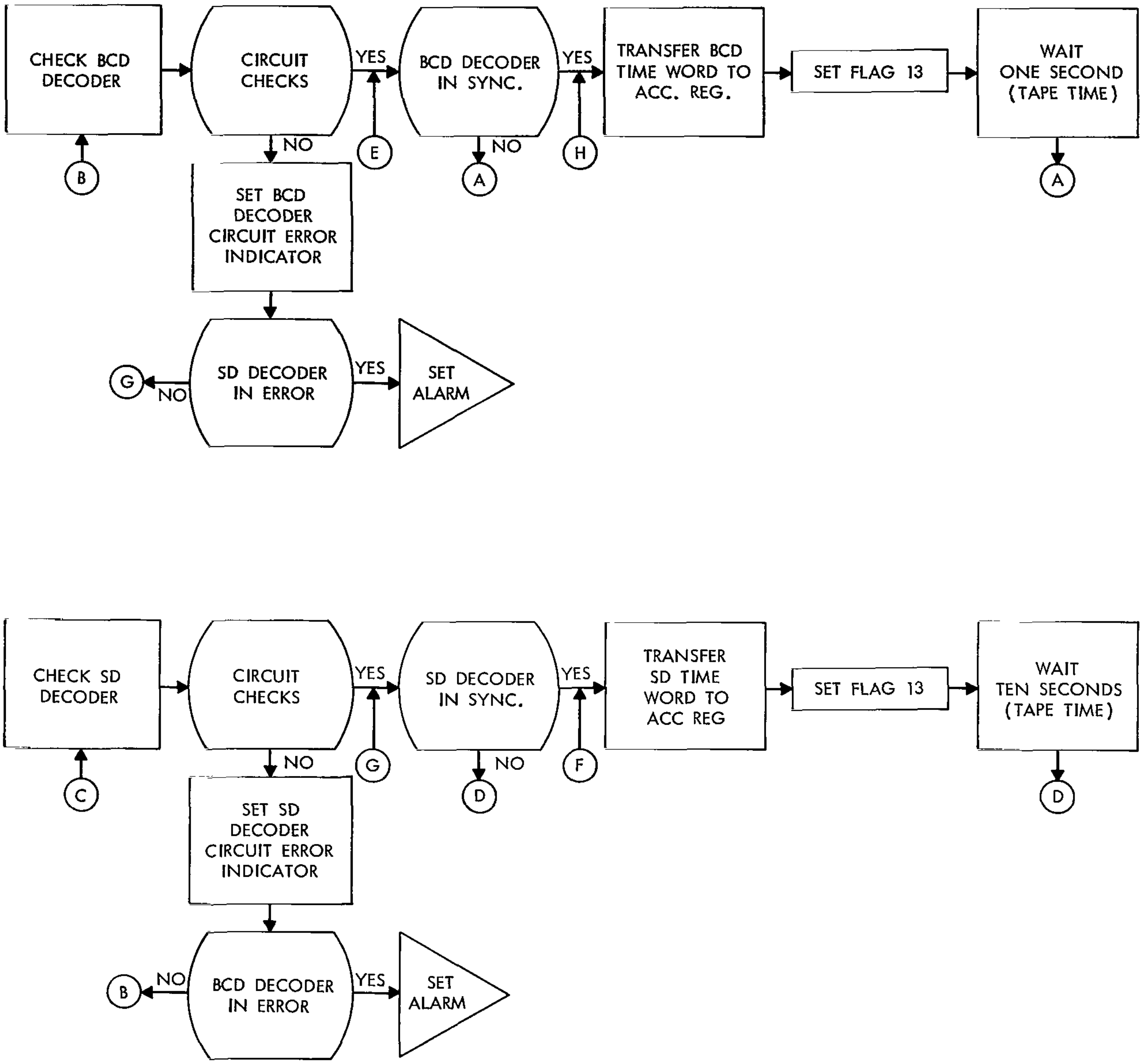


Figure 5 (continued)—Comparator control flow diagram.

and in the satellite, the command tone was also recorded on the satellite's tape recorder. Commutated on the signal recorded onto the satellite tape recorder was a standard frequency, so that time intervals to the accuracy of the frequency generator were known. Since the command tone was recorded on the tape at the time it was received by the satellite, it was also heard at the end of the satellite tape recording. Thus, throughout the recorded data, known time intervals were marked, and, in addition, the universal time of one data point, namely, the command tone, was also known. By extrapolation, therefore, Universal Time could be assigned to any of the recorded data points. One serious limitation to this method is that if the playback command data point is lost in any way (for example, by signal fade either to or from the satellite), then the time relationship of all the data from the satellite tape recorder is also lost.

There is a trade-off between the dependability of time correlation and the proportion of channel capacity used for time read-ins. The Orbiting Geophysical Observatory series of satellites requires a more dependable system. Here a PCM telemetry is used. A binary number related to elapsed time from launch is subcommutated onto both the real time format and the satellite recorded data format. Counts derived from a fairly stable and precise oscillator are used to update a register in the satellite, and the contents of this register are read-out periodically and automatically as part of the telemeter information. The correlation of the data with the number in that register is thus an inherent part of the telemetry. Note that this system devotes a significant proportion of its telemetry channel capacity to the time-correlation function. The correlation of that number in the register with universal time can be made as often as necessary during periods of real-time data transmission in the same way we have been talking about correlating any data with time. If we could assume the oscillator in the satellite to be perfectly stable and precise, only one such correlation with real time need ever be made. Since the oscillator will not be perfectly precise in the space environment, periodic correlation checks might well be made. The function, which correlates the number in the register with Universal Time, can be expressed, over intervals, as a polynomial, the degree of which is determined by the behavior of the satellite's oscillator. Solution of the coefficients of this polynomial, and predictions once these coefficients are known, are problems which lend themselves to stored program computer techniques.

CONCLUSIONS

An error detection and correcting time decoder has been designed for, and is currently used with, satellite data processing facilities to cope with the erroneous time readings in telemetry tapes. This decoder is an improvement over the straightforward instance-by-instance time decoding (called multiple read-in) in that short-term perturbations in the time code will not produce an incorrect output from the decoder. This decoder is an improvement over a single read-in method of data-time decoding updated by a standard frequency in that it continually correlates the time words with the data. The decoder further decodes both a serial decimal time code and a binary coded decimal time code, compares them with each other and with the accumulating register, and flags each time reading to indicate the amount of confidence the experimenter can place in its accuracy. It also incorporates self-checking circuits to reduce the probability that a malfunctioning decoder component will provide an incorrect time reading.

ACKNOWLEDGMENT

The authors would like to acknowledge William H. Stallings and Gary W. Nooger for their contribution to the design of the decoder.

(Manuscript received December 27, 1965)

Appendix A

Operation of the Time Encoders in the Receiving Stations

The Network Operations Branch of the Network Engineering and Operations Division, GSFC, has established a standard procedure for checking and resetting clocks at the Minitrack stations to minimize operator error. This procedure requires operators to check clocks, countdowns, and coded time readout to the millisecond with WWV prior to each pass of a satellite, at the beginning of each shift (every eight hours) if a pass is not in progress, every half-hour (or oftener) during a pass; and at the end of each pass. If any error is noted, the operator is expected to correct the error. If the error occurs during a pass, the discrepancy will be noted, recorded, and corrected after the pass. The operators are also required to check their time standard with the 15 Mc WWV time signal (or another WWV frequency if the 15 Mc signal is not obtainable) once a day and note the offset to the nearest millisecond. If WWV is not obtainable because of propagation conditions, a local time standard (e.g., ZUO in South Africa) may be used. The time checks are made at the same time each day, plus or minus a half-hour, to minimize errors due to diurnal variations in the propagation time. If the oscillator causes an error greater than one millisecond per day, a correction is made to reduce this error to less than a millisecond per day. The entire time encoding equipment is supplied by battery power in the case of an a.c. power failure. All checking and resetting data are entered in a log, a copy of which is periodically forwarded to the Network Operations Branch.

There are at present two types of oscillators used in the STADAN stations. The old type oscillator (100 kc) is precise to 1 part in 10^8 for a 24-hour period. The new type oscillator (1 Mc) is precise to 5 parts in 10^{10} for a 24-hour period.

Assuming that the tracking station operators are following the standard operating procedures, the present overall probable error with respect to WWV in the time recorded on the tapes at the stations is approximately 1 millisecond. Part of the error is due to the uncertainty in the propagation time, and this can generally introduce an error of approximately a half-millisecond. The other half-millisecond of error is introduced in the tracking station, most probably in the offset of the station time standard with respect to WWV. This maximum error of one millisecond has been fairly well substantiated by surveys made by the Network Engineering Branch of the Network Engineering and Operations Division.

Appendix B

Time Decoder Status Flags

Flag	Meaning
1	The BCD decoded time agrees with the accumulating register.
2	The BCD decoded time disagrees with the accumulating register.
1 and 10	The BCD decoded time agrees with both the accumulating register and SD decoded time.
1 and 9	The BCD decoded time agrees with the accumulating register, but disagrees with the SD decoded time.
2 and 3	The BCD decoded time disagrees with the accumulating register, but agrees with the SD decoded time word.
2 and 4	The BCD decoded time disagrees with both the accumulating register and SD decoded word.
5	The SD decoded time agrees with the accumulating register.
6	The SD decoded time disagrees with the accumulating register.
5 and 7	The SD decoded time agrees with the accumulating register but disagrees with the BCD decoded time.
5 and 8	The SD decoded time agrees with both the accumulating register and BCD decoded time.
6 and 7	The SD decoded time disagrees with both the accumulating register and BCD decoded time.
6 and 8	The SD decoded time disagrees with the accumulating register, but agrees with the BCD decoded time.
11	The BCD-to-binary converter circuit is in error.
12	BCD time code input error.
13	The accumulating register has been reset.
14	The BCD time code input voltage dropped below the operating threshold.
15	The linearing frequency input voltage dropped below the operating threshold.
16	The SD time code was not detected.

NASA-Langley, 1966

"The aeronautical and space activities of the United States shall be conducted so as to contribute . . . to the expansion of human knowledge of phenomena in the atmosphere and space. The Administration shall provide for the widest practicable and appropriate dissemination of information concerning its activities and the results thereof."

—NATIONAL AERONAUTICS AND SPACE ACT OF 1958

NASA SCIENTIFIC AND TECHNICAL PUBLICATIONS

TECHNICAL REPORTS: Scientific and technical information considered important, complete, and a lasting contribution to existing knowledge.

TECHNICAL NOTES: Information less broad in scope but nevertheless of importance as a contribution to existing knowledge.

TECHNICAL MEMORANDUMS: Information receiving limited distribution because of preliminary data, security classification, or other reasons.

CONTRACTOR REPORTS: Technical information generated in connection with a NASA contract or grant and released under NASA auspices.

TECHNICAL TRANSLATIONS: Information published in a foreign language considered to merit NASA distribution in English.

TECHNICAL REPRINTS: Information derived from NASA activities and initially published in the form of journal articles.

SPECIAL PUBLICATIONS: Information derived from or of value to NASA activities but not necessarily reporting the results of individual NASA-programmed scientific efforts. Publications include conference proceedings, monographs, data compilations, handbooks, sourcebooks, and special bibliographies.

Details on the availability of these publications may be obtained from:

SCIENTIFIC AND TECHNICAL INFORMATION DIVISION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. 20546